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THE UNIVERSITY OF ALBERTA

ETHICAL AND SOCIAL RESPONSIBILITY IN SCIENCE EDUCATION

BY

PINA MARTINOVICH

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF EDUCATION

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EDMONTON, ALBERTA

FALL, 1994

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(Signed): P. Martinovich

PERMANENT ADDRESS:

8512-190 Street

Edmonton, Alberta

T5T 4Z9

DATED: August 23, 1994

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "Ethical and Social Responsibility in Science Education", submitted by Pina Martinovich in partial fulfillment of the requirements for the degree of Master of Education.

(Dr. Wallie Samiroden, Supervisor)

(Dr. W. Brouwer)

(Dr. A. Pearson)

Date: August 23, 1994

ABSTRACT

This study attempts to reveal the manner in which students perceive the relationship between science and society. Students were involved in studying science related social issues, many of which were controversial in nature. By placing the context of science within a social setting, where controversial issues were introduced at relevant points of the curriculum, students were asked to explain how they have come to understand the nature of science and whether or not they perceived a relationship between science and society.

Science 10 students were involved in studying controversial issues at relevant points of the curriculum. By relating science instruction to the students' life experiences and the social issues they face, as a teacher I was able to motivate them and deepen their understanding of the value of science to society. The study focused on engaging students in decision making processes related to STS issues. Certain controversial issues studied throughout the course raised many ethical and moral questions which in turn, required students to re-examine and reflect on their own personal perspectives, while respecting other individual differences and points of view.

The study was qualitative in nature and involved action research. Students were responsible for much of their own learning and research involving societal issues. As a teacher, I became a

collaborator in student construction of knowledge versus a distributor of knowledge.

The implementation of a more student-centred program gives students the responsibility of doing their own research. Incorporating activities which relate science to society enables students to see science from a different perspective and enables them to transfer their knowledge to their daily lives. Thus, science can be seen as relevant to their futures.

In the research it was important that science be presented as tentative and scientific knowledge having ethical implications for society. Religious values were incorporated enabling students to integrate their faith with the scientific enterprise. Science is presented as a human endeavour where there is a sense of moral responsibility that comes with learning. Moral responsibilities are a key part of acquiring knowledge for it allows students to make thoughtful decisions - a skill that is critical in becoming scientifically literate.

My study attempted to develop a greater understanding of how students conceptualize science by encouraging the development of attitudes, values, and a critical awareness of the applications and ethical implications of scientific and technological knowledge. The project examined how students conceptualize the nature of scientific knowledge and the implications this knowledge has for society. The study also gives suggestions and teaching strategies

teachers can use when implementing societal/controversial issues in classroom practice.

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I owe special thanks to my parents, Frank and Frances Rizzuto, who have inspired and challenged me to strive for excellence and have shown me the importance of ethics and values in my own life.

Finally, I wish to thank my husband Stanley, and daughter Vincenza, for their continual love and support throughout the duration of this study.

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SECTION ONE: THE STUDY

CHAPTER ONE
COMING TO THE QUESTION
Pedagogical Storying
Hearing My Own Voice

To narrate is to give an account of something, in one sense to tell a story. Story-telling about pedagogy allows us to articulate that which is silent. It allows us to help others understand educational/life issues that relate to the teacher/student relationship. As Max Van Manen writes,

> *"As we research the possible meaning structure of out lived experiences, we come to a fuller grasp of what it means to be in the world as man, woman, a child, taking into account the sociocultural and historical traditions which have given meaning to our way of being in the world". (Van Manen, 1990)*

Stories allow us to gather other peoples' experiences and in a vicarious sort of way to become more experienced ourselves. Through stories we are able to experience life situations, events, and emotions we may not experience. Through stories, then, we are given the chance of living through an experience that provides us with the opportunity of gaining insight into certain aspects of the human condition. Let me continue by recounting some of my own experiences.

It is 1984, my first year of teaching in a rural community 100 km from Edmonton. I am standing in front of my students, my desk and blackboard behind me. I'm afraid. I am grasping the textbook for security because it contains the information I am about to give these students. I talk about the ideas in the book, have students do the problems and questions in it, and then use it to check their answers. The textbook is my curriculum. It keeps me distanced from the students, from learning about them as people. Students are evenly seated at a safe distance from me, at desks in traditional rows separated enough so that no talking will occur. Some of them are bored, yawning, fiddling with their pencils but at least they're not making any noise. One of the students proceeds to stand up in the middle of my lecture and recites a joke. The

class breaks into laughter. They are anxious to see my reaction. My stomach begins to churn, my face reddening. How can I get them to listen? to be quiet? They are quiet for a few minutes, the noise level rises again, I yell some more and the cycle continues over and over again, day after day.

I accidently overhear a conversation in the staffroom that I won't last as a teacher - I'm not aggressive enough. Even my own colleagues have no confidence in me. I exist solely from day to day alone - away from my family and friends. I cry myself to sleep. I live for weekends, vacations, school assemblies, for any time when I don't have to teach. This is how the school year progresses.

As I now write, recalling this experience I think about who I was in 1984 - young, inexperienced, fearful and uncommunicative. I lived in a numbness that allowed me to be perfectly functional in the classroom. My teaching mirrored the being I was then. In my fear, my uncomfortableness with who I was, I slipped into a power struggle with my students. Cliches like, "*Don't smile until Christmas. Be tough at first you can always loosen up. Don't let the students get the upper hand*" became a reality. This language of power and control kept me distanced from the students I taught.

My educational training in the sciences also focussed on a separation and fragmentation of physics, chemistry and biology from the people I was to teach. The content or prescribed curriculum was the concern and not the students who were to learn these ideas.

Insecurity and fear distanced me from my students and colleagues. I hated teaching. Living became a mechanical process, a numbness and inability to feel emotion for the students I was with. Could this be what teaching was all about? Was this what I was about to do for the next thirty years of my life? Now I knew the meaning of the phrase teacher burn out. Who was I to turn to - my administration? They would not renew my contract and then it would be difficult to find a job. My colleagues? Their initial response that I would not last for more than six months would be confirmed. The problem was mine and I had to find a way to cope.

The next year I was offered a contract with another school board and decided I needed to reflect on how I was going to make things different in my new school. There was an inner desire to take action and alter my beliefs and behaviours. There has to be a way of teaching the content and at the same time interacting with my students from a position of caring and cooperation, and making this mechanical process of teaching more interesting and motivating for students.

As the year progressed, the need for power and control transcended. Conscious awareness of my behaviour began, as well as alterations in that behaviour. My teaching became an experiment in communication between my students and me. I began listening to their voices, their ideas and found that they respected me for that. No longer was the textbook the sole curriculum. The language I began to use was not one of power and control but one of caring and concern.

There is a tension with this dialogue however, with the increasing pressure of standardized testing, fewer electives, back to the basics and teacher accountability. These are expressions of a process-product paradigm which is political in nature. The language of school, with its emphasis on rigor, control, grades, testing, information and with its pronounced distinction between students and teachers have led to a stereoscopic image of what teaching should be. This has left teachers with the inability to articulate their own views in any meaningful way. Schooling continues to imitate the ritual order of industry and bureaucracy. Living in this gap means trying to balance this preoccupation in the world of objective meanings through the instrumentality of science/technology and not forgetting the essence of "*being*" and teaching. The concern with people leads to a personalized curriculum; to one that is not routinized or standardized, but to one that is meaningful to students. It is a curriculum that often allows for interpretation, one for which problems do not always have one right answer and/or one right way of doing those problems. It is one that allows for ownership by students, one for which problems and questions are so involving that students or the teacher cannot stay distanced.

My pedogogical experience as a mother in the last three years has also confirmed for me the need for education to examine closely all that is done in the classroom. When my daughter was born on July 14, 1991 it was the most wonderful experience of my life. The minute they put her in my arms I realized how precious and fragile this child was. Having a child has put into perspective the dialectical relation between what Grumet calls the domestic experience of nurturing children and our project to educate the next generation. Someone once told me that having my own child would make me a better teacher. At the time I felt offended by the statement. Now I realize its truth. I have come to a deeper understanding on what Grumet means by the domestic experience of nurturing children and the importance of this experience. (Grumet, 1988)

The two above pedagogical experiences have led me to reflect on my own role as a teacher and helped me form the educational questions for this study.

This study emerges out of the silence of questing and searching for what it means to educate children holistically. My study is therefore deliberately biased, because much stems from a Roman Catholic tradition. It is conceived and nurtured out of a particular view of myself, my church, my world.

The biased way of writing is supported by many educational researchers who hold that not only is it not possible to do value free research but that it is not desirable to want to do so. A purely objective approach would ignore the importance of the inter-relationship of the subject who poses the question with the reality of who or what is being researched. Thus, a qualitative methodological approach was used in this study where meaningful description and interpretation of events and phenomena could be a focus for inquiry.

The need to focus on studying controversial issues in the research stems from the notion that much of the knowledge students attain in science is not value free, and in many instances has ethical implications for society. We live in a society which continually requires us to make ethical decisions, so it is vitally important that students be equipped with the necessary skills to make these decisions. This process involves skills such as collecting information, analyzing

alternative viewpoints and working together with fellow classmates. This decision making process not only allows students to examine alternative viewpoints but to question their own perspective and world view. This can lead students to a more reflective and broader world view, which ultimately can create more responsible citizenship in society.

Narrow mindedness often creates societies with little tolerance for the perspectives and beliefs of others, for they believe that their framework or world view is the correct one. By studying controversial issues, hopefully students can expand their understanding of various viewpoints and learn to respect the opinions and viewpoints of others. Knowledge in this domain is holistic and subjective and can lead to the betterment of humanity and society as a whole.

CHAPTER TWO
PURSUING THE QUESTION

Introduction

Contempory science education at the secondary level is often based on the idea that science is neutral, value-free and isolated from questions of values and ethics (Frazer, 1986). There is a growing awareness that beliefs and values permeate the curriculum and they need to be treated seriously as part of the educational process. Now that science is seen increasingly as a social activity, science and society components, with their inevitable value judgements, are more and more evident in science courses (Gosling, 1985). This interrelationship between science and society encourages the development of attitudes, values, and a critical awareness of the ethical implications of scientific and technological knowledge in classroom practice.

The new senior high science programs in Alberta are designed to help all students attain the scientific awareness needed to function as effective members of society. The focus of the program is to help students attain a level of scientific awareness essential for all citizens in a scientifically literate society. The senior high program centers on increasing students' understanding of the science knowledge, science process, and the connections among sciences, technology and society. The students are involved in explaining and evaluating for a given instance, and from a variety of different perspectives, how science and technology are influenced and supported by society. They are involved in assessing the ability and responsibility of society, through science and technology, to protect both environment and humanity.

The senior high programs encourage students to participate actively in their own learning. The context for learning is relevant so students can experience science as interesting and dynamic. Working together with others to solve problems is another important aspect of the learning. This encourages co-operation, open-mindedness and respect for the points of view of others.

Purpose of the Study

The intent of this study was to examine how students conceptualize the nature of scientific knowledge and the implications this knowledge has for society. The basic question was - "*How do students perceive the interrelationship between science and society?*" The participants of the study were grade 10 science students in three different classes. A total of 53 students were involved in the study. Controversial or societal issues were introduced at relevant points of the science 10 curriculum. Controversial issues are those topics which are publicly sensitive and on which there is no consensus of values or beliefs. By their nature, controversial issues generate diverse opinions and debate on the distinctions between right and wrong, justice and injustice, and on interpretations of fairness and tolerance.

Sensitive issues and topics are an integral part of the education programs and schooling process in Alberta. Often as teachers we are faced with an already overcrowded content focused syllabus or curriculum which creates barriers to raising societal and ethical issues. Additional reasons for failing to raise societal or ethical issues include inadequate knowledge of the facts surrounding debatable issues and a lack of usable material in print.

This study is based on the assumption that knowledge is not neutral. It is important for students to get a realistic conception of the nature of the scientific enterprise. Controversial issues must be handled in a manner that respects the rights and opinions reflected in different perspectives.

During the research students had experiences in selecting, organizing and evaluating information. The educational benefits gained by studying controversial issues included the development of critical thinking, moral reasoning, and an awareness and understanding of contemporary society. Studying controversial issues prepares students to participate responsibly in a democratic and pluralistic society. Such study provides opportunities to develop

student's capacities to think clearly, to reason logically, to open-mindedly and respectfully examine different points of view, and to reach sound judgements.

The following sub-questions focused my research:

1. How do students' personal histories influence their interpretation of science in relation to the ethical and social problems for which they bear responsibility as citizens?

2. How does a students' faith or religious perspective influence the nature of scientific knowledge?

The latter sub-questions were addressed by a personal interview as well as continual use of dilemmas or controversial issues throughout the Science 10 course. Dilemmas were used to help attain a major goal of science education - to develop in students an ability to discuss rationally and intellectually, and make decisions about the problems facing our society today. Students need to explore and discuss the positive and negative aspects of controversial topics that involve science, technological developments and societal issues if there are to become scientifically literate citizens.

Dilemmas are problematic situations with no easy solutions. They require a good background knowledge in science and specific skills in critical thinking and problem solving if students are to propose solutions to these problems. Various classroom teaching strategies can be used to bring forth the issues surrounding the controversy and help students to clarify their thinking regarding the dilemma.

Dilemmas can: **(Alberta Education, 1994)**

- provide insight into the complexity of today's issues
- help develop communication, decision-making, and critical thinking skills
- promote tolerance and understanding of alternative perspectives
- promote the notion that ordinary citizens have a role to play in decision making
- encourage personal action

There is much more than an emphasis on a specific body of knowledge and skills in science education. There is often the implicit or explicit development and education of the "*total*" person, the intellectual, physical, affective, social, aesthetic, and religious.

> "*Today we can point to the importance of social, aesthetic and religious experience and the need to go beyond science in gaining a more holistic understanding of the world. As teachers, we have a responsibility to help students see the findings of science within a larger framework of meaning.*" *(Gosling and Musschenga, 1985)*

It seems to be an inescapable fact of life that values direct and govern the actions of people, institutions, and society. The school, as a major extension of the home in our contemporary culture, cannot avoid its share of the responsibility, or its significant opportunities in developing positive attitudes and thinking in the moral and values dimension.

We misunderstand what it is to be a teacher if we think that teaching simply means to hand over or convey subject matter. Actually, teaching is far more. Teaching is the creation of a situation in which human subjects are handed over to themselves. **(Rice, 1992)**

There is a fundamental recognization in the above statement that is inherent in this study. Education is never a neutral act. What we teach or do not teach and how we teach it offers powerful value messages to our students. (Freire, 1970) Before presenting the methodology, the way in which the study was carried out, it is important to state some basic assumptions regarding the nature of the study:

a) The decisions that scientists and society make regarding scientific knowledge and technology are no value free. It is important that students understand that science is not purely objective.

b) The impact of science and technology on society and individuals is not necessarily beneficial.

c) As educators we must realize that there are ways of knowing other than scientific. Science students will meet science in relation to the social problems for which they bare responsibility as citizens.

d) Science education must focus more on teaching how to use scientific knowledge and skills in personal and social life.

e) Science has been seen as rational and objective and ethics as non-rational, relativistic and subjective. We must find a new way of looking at ethical and societal problems in relation to science.

f) Most ethical and social problems necessitate collective decisions. Education must direct itself the question of how groups or society as a whole can decide on problems about which people fundamentally disagree. In a classroom setting it is not sufficient for students to learn to express their views, they must also learn to justify them.

How the Question Was Pursued

A qualitative methodological approach was used in the study. The research involved introducing societal issues at relevant points of the Science 10 curriculum. This methodology of teaching enabled students to make connections between what they learned in science class and the manner in which they experienced science in everyday life. The controversial issues discussed not only identified the important societal effects of a scientific principle; the issues were value - laden. The issues demanded the intellectual as well as the emotional participation of the students. The goals of the research were to foster reflective student thought and reasoning skills. Students gained an understanding of the nature of science by becoming involved in science related discussions. It was important that students recognized that scientific theories change or are modified as additional information is provided or as social views are altered.

> *"Science does not provide absolute truths but offers an approach for interpreting nature. Most research answers some questions but raises many others. Research is rarely terminal." (Ritter, 1992)*

The methodology of the research included the following dimensions:

A) Written Essay

In September of 1993, students were asked to respond individually to the following questions:

1. In essay form, describe as best as you can, what science means to you. (*i.e., What is science?*)

2. Does the study of science relate to society? Explain why or why not.

3. Is there a connection between science and religion? Explain why or why not.

Students were explicitly told that their answers were confidential and were being used in research to try to gain a more accurate understanding of how students viewed the nature of science.

The three questions were then again posed near the end of November, 1993. Students were given back their original questions and responses and asked to re-read their answers to make any deletions, corrections or additions.

B) Introduction of Controversial Issues at Relevant Points of the Science 10 Curriculum.

The Science 10 curriculum is a general program involving studies in biology, chemistry and physics. Four basic units comprise the curriculum and two controversial issues per unit were introduced.

Issues presented in the research include:

a) Greenhouse Effect

This issue relates to Unit I, Chapter 1 of the Science 10 program. Students were given scientific information regarding the nature of the Greenhouse Effect. Students were divided into groups and asked to discuss five ways or solutions for decreasing the greenhouse effect that could be used in their daily lives. Once student groups had a chance to write down their ideas, a group leader was responsible for articulating and sharing the ideas with the entire class.

b) Deforestation Written Reports

Students were asked to research the effects of deforestation on the environment. Pros and cons of the issue were addressed. This project was done individually. The reports were placed in student portfolios and some reports were published in the school newspaper and placed in the science display area.

The deforestation topic relates to Unit I, Chapter 1 of the Science 10 curriculum.

c) Water Conservation

In the study of water the following topics were discussed:

i) Class discussions on underground water contamination and toxins in the food chain;

ii) Methods were discussed on how students could conserve water on a daily basis. Water conservation tips were placed in students portfolios.

The unit on water relates to Unit I, Chapter 2 of the Science 10 curriculum.

d) Environmental Survey

The environmental survey was comprised of a general array of questions focusing on how people deal with environmental issues on a daily basis. Students were asked to complete the survey and tabulate their results on a corresponding scale (See appendix). The scale indicated to the students whether or not they were environmentally friendly. Students were asked to reflect and discuss how they and their families could increase their environmental awareness. The environmental surveys were placed in the student portfolios.

e) Biotechnology Debate

Students were involved in researching a particular viewpoint regarding the field of biotechnology. Each group was responsible for collecting scientific data supporting their viewpoint and the presentation of their position in a debate format. The perspectives included the following:

i) Benefits of Biotechnology

ii) Risks involved in Biotechnology

iii) Future consequences of the Technology

iv) Catholic perspective on the techniques used in Biotechnology

v) Role of the Scientist

The debate methodology was followed by class discussion. The unit on Biotechnology relates to Unit II, Chapter 4 of the Science 10 curriculum.

f) Pesticide Article From Daily Journal

Students were responsible for reading the article and answering five questions:

i) What is a pesticide?

ii) Why are pesticides used?

iii) What are alternative methods to the use of pesticides?

iv) Give two negative side effects of using pesticides.

v) DDT is no longer used in Canada. Why was this pesticide banned?

Students were also responsible for collecting articles on the effects of pesticides on the environment and placing them in their portfolios. The unit on pesticides relates to Unit II, Chapter 6 of the Science 10 curriculum.

g) Cloning of Human Embryos

The controversial issue of cloning human embryos appeared in the journal, and several news telecasts as well as journals such as Time magazine. Students were involved in collecting data from these sources and researching a particular viewpoint or perspective. The perspectives included the following:

i) Benefits of cloning

ii) Risks involved in cloning

iii) Future Consequences of the technology

iv) Catholic perspective regarding cloning

v) Role of the Scientist

Students were responsible for a written summary of their perspective as well as the presentation of their particular viewpoint. Students used a wide variety of presentation styles: role-playing, use of audio-visual material, production of their own video and displays, as well a debate format.

The controversial topic of cloning relates to Unit II, Chapter 4 of the Science 10 curriculum. The study of cells and how they reproduce connects thematically with the issue of cloning.

h) Chemical Technologies

I. Students were to choose from the following topics:

i) *Radioactive Waste Disposal.*

The disposal of long-lived radioactive chemicals and waste products form the world's nuclear reactors and medical communities poses many problems.

ii) *Mercury Fillings and Kidney Disease.*

Mercury has long been cited as problematic yet dentists continue to use it for fillings.

iii) *Hazardous Chemicals Dioxin and Molecular Formulas.*

Toxicologists have often incomplete information on the health hazards of certain chemicals.

iv) *Heavy Metals in Living System - Lead and Cadmium.*

Most living organisms are adversely affected by low doses of heavy metals in their systems.

v) *The Study of Subatomic Particles.*

Particle accelerators are expensive pieces of equipment. How should the budget for these projects compare to the budgets for other research endeavors, such as medical or environmental research?

vi) *A Current Chemical Technology.*

Discuss the political, scientific, economic, ethical and social issues surrounding the use of a particular chemical technology.

II. Science is rarely as definite as most people believe. Answers are challenged. The challenge may not even be directed at research methodology, but at interpretation of research data.

a) Outline the major scientific components of the issue. What is the problem?

b) Identify and explain two divergent views of the problem and the solutions imposed by each. Discuss the consequences of each viewpoint and the rationale that accompanies it.

c) Identify a situation in the news, in a journal, a historical event, a personal/human experience, where the issue was a concern.

d) Outline your personal viewpoint and the reasons why you have accepted this viewpoint.

III. Methodology

1. Report of findings must be handed in.

2. Methods of presentation can include:

a) Role-playing

b) Debate

c) Oral presentation

d) Play/Drama

e) Alternative Method

The topic of chemical technologies relates to Unit III, Chapters 7, 8 and 9 of the Science 10 curriculum.

i) Conservation Action School Program

Students were responsible for designing procedures that would enable them to conserve energy both at home and in the school community. Activities included:

a) Calculating Carbon dioxide emissions in the school, and comparing them to other schools. In order to complete the calculations students were required to calculate the annual gas consumption in Giga Joules *(GJ)* and the annual electricity consumption in kilowatt hours *(KWh)*. Students also discussed methods in which they could reduce CO_2 emissions in the school.

b) School Audit Check-list. Students were involved in researching energy consumption of:

a) photocopiers

b) printers

c) computers

d) air circulation

e) recycling

f) toxic waste

g) water

h) lighting

Students were also involved in discussing methods of energy conservation and its effects on society. The Conservation Action Program corresponds to Unit IV, Chapter 11 and 12 of the Science 10 curriculum.

C) Portfolio Work

Portfolio assessment was used in the research. Portfolios were a collection of the student's work on controversial issues. Students were also encouraged to read the newspaper on a daily basis and incorporate relevant newspaper articles in their portfolios.

D) Student Interviews

Student interviews were conducted at the end of the Science 10 course. Each interview was approximately 10 minutes long and students were asked the following questions:

1 a) Did you enjoy the portfolio work on societal issues?

Yes _____ No _____

b) Do you feel that the evaluation of the portfolio (ie. 10% of total science mark) was fair?

Yes _____ No _____

c) Did you gain more insight and knowledge about societal issues by doing the portfolio?

Yes _____ No _____

2 a) Have you ever discussed controversial issues in relation to science and society in other science classes?

Yes _____ No _____

b) What types of issues have you discussed? _____
_____
_____
_____
_____

3 a) What is your age? _____

b) What is your sex? _____

c) Are you a Catholic? _____

4. Have you ever done the following activities in other science classes: *(ie. if you answer yes, how often)*.

a) Role-playing. Yes _____ No _____

b) Debates. Yes _____ No _____

c) Experiments. Yes _____ No _____

d) Discussion of relevant societal issues as they relate to science.

Yes _____ No _____

e) ORAL reports on controversial Issues. Yes ____ No ____

f) Guest speakers on controversial issues. Yes ____ No ____

g) Portfolio work on controversial issues. Yes ____ No ____

5. How is science different from other subjects?_____
_____
_____

6. Do you see a relationship between science and society? Please explain.
_____
_____

7. Has religion been incorporated in your science classes before?

Yes _____ No _____

8. How would you rate the importance of relating science to what's happening in society?

Extremely Important _____

Very Important _____

Important _____

Somewhat Important _____

Not Important _____

9 a) Do you read the newspaper on a regular basis to inform yourself on societal issues?

Yes _____ No _____

b) How often? _____
_____
_____

10 a) Did you enjoy studying controversial issues this year?

Yes _____ No _____

b) Has it helped you understand the relationship between science and society?

Yes _____ No _____

11. What does it mean to be scientifically literate? _____

_____

_____

The interview process was utilized instead of giving out a questionnaire to students for the following reasons:

1. Students could ask me to further explain a question if they did not understand it. I was responsible for recording information as the student spoke.
2. The questions posed and the students responses often lead to further discussions and insight. Often, I would ask students to further explain their answers.
3. Student portfolios were discussed and students gave feedback as to how they felt about studying controversial issues.
4. The one to one personal interaction with the student was beneficial and meaningful to me as a researcher because it provided me with additional insight and information about student attitudes and conceptions of the scientific enterprise. As a researcher, I have found that an interview is much more subjective and humanistic. Students approached the interview seriously and did not rush through it as often happens when responding to a questionnaire.

Delimitations

The scope of this study was delimited to the study of my own Grade 10 science students. This approach did not attend to observing other teacher's approaches of studying controversial issues in their classrooms.

As a justification for this single classroom approach I would point out that the study was centered on a question directly related to teaching. Therefore the study required concentrated attention on the teaching activity given the time restrictions of the research. Furthermore, my own personal intent in introducing controversial issues at relevant points of

the science curriculum gave rise to studying my own classes and students so I could come to a better understanding of the process involved.

Limitations

There are two major limitations to the study. One limitation is that the research was conducted in a Catholic school setting where both divergent perspectives and the integration of subject matter with religion/ethics are encouraged.

A second limitation is that I decided to work with grade 10 science students only. No other grade levels were examined.

Definition of Terms

Controversial Issues: Controversial issues are those topics which are publicly sensitive and on which there is no consensus of values or beliefs. *(Alberta Education Program of Studies).*

Value: Values are ideals, good ends we ought to pursue. They are of various kinds: moral values like honesty, political values like equal justice for all, intellectual values like truth and understanding, aesthetic values like beauty, social values like friendship. *(Holmes, 1991)*

Ethics: Ethics is not a means of inculcating certain norms of moral behaviour in others (*such as students*). Whether philosophical or theological in nature, ethics is a critical, rational discipline which examines the advantages and disadvantages of all alternative courses of action and which places great emphasis on individuals making their own moral decisions. *(Crowford, 1988)*

Moral Education: Committed to promoting in people a desire to achieve the greatest possible knowledge and understanding of whatever kind will help them to reach autonomous choices which are based on careful and informed thinking about the issues involved. *(Downey and Kelly, 1978)*

Education: Education is a process of becoming aware of life's thrust and orientation towards wholeness and completeness. As an intentionally critical and creative encounter with reality, education awakens in human beings a sense of responsibility towards action that promotes human dignity and solidarity and contributes to individual growth and the on-going transformation of society. *(Religious Studies Program)*

Morality: to be moral, or to act morally, a person must believe in some values and have the will to act accordingly. *(Religious Studies Program)*

Integration of Values: values are not taught as separate entities but introduced in the curriculum at relevant points (holistic approach).

This chapter has focused on addressing the research question and how the question was pursued. Students were active learners and assumed increased responsibility as they studied controversial issues. Students were encouraged to make appropriate applications of scientific concepts to their daily lives. As well, students were involved in discussing the limitations of science and technology in answering questions and solving problems.

CHAPTER THREE
SITUATING MY RESEARCH METHODOLOGY

Introduction

In Chapter Two I described the method used in the study. My research question addresses the importance of showing the relevance of course material to students' daily lives and the introduction of societal issues that affect communities and the world. The intent of this chapter is to discuss the nature of scientific knowledge and to reflect through examples how controversial or societal issues can be integrated into science core material.

Nature of Scientific Knowledge

Science has often been viewed as a branch of knowledge involving systematic observation of and experimentation with phenomena. Traditional approaches to science teaching have impeded growth toward scientific literacy by emphasizing memorization of isolated bits of information without fostering critical thought and free exchange of ideas. This approach, often called a results based curriculum, tends to exclusively emphasize what is "observable" and "measurable". In a result based curriculum, the focus is on intended educational results. This approach promotes an excessively narrow view of learning and education.

> *"The danger comes in assuming that the worth and the depth of an individual can be measured by comparing to a list of desired "results". Does this leave room for intuition, invention or creativity?" (ATA, Trying to Teach)*

The focus on what can be seen as an end product tends to imply that education is product driven. A result based curriculum encourages us to teach toward the test. Teachers often feel that their merit is being judged on the basis of their students' achievement test results. This encourages teaching for rote memorization rather than application and process skills. A result based curriculum seems to stress producing highly trained, intensely educated individuals. This suggests homogeneous grouping of students with narrow educational goals and teachers focused on getting the most information into them in the shortest time. Teachers are considered technicians in this paradigm.

The way we view our world and knowledge is often a reflection of our culture and our up-bringing. "*Our moral opinions are conditioned by our environment and upbringing. Human beings live in accordance with the ways they have learned*". (Satris, 1992) Ethnocentrism is the point of view that one's own way of life is to be preferred to all others. This type of philosophy leads to a very narrow minded vision of the world and a lack of cultural diversity and acceptance of other points of view. "*Morality differs in every society, and is a convenient term for socially approved habits*". (Satris, 1992) Becoming conscious of this enculturative conditioning in shaping our thought and behavior enables us to begin to break through the barriers and become more acceptable of other peoples' visions, ideas and points of view.

One of the major objectives of the research was for students to come to a greater understanding that science related social issues are inextricably tied with an understanding of scientific knowledge. The recent science-technology-society trend within science education has stressed the importance of understanding the nature of science. The concept of the scientific enterprise is a topic that does not receive sufficient instructional attention. Questions addressed throughout the Science 10 program include:

a) Is science tentative? Did you change your ideas when you tested a hypothesis and found it to be incorrect?

b) Is science public? Did you communicate your findings to others and to the class?

c) Is science verifiable? Did you test to confirm some of your ideas as well as those of other students?

The above characteristics of science represent a particular philosophy, or a particular method of knowing. This method of knowing is called empiricism, a method that assumes nothing is real that cannot be directly observed. Other systems of knowing, however, do exist. Science is interconnected with economics, aesthetics, religion and sociology. Technology is the application of scientific knowledge for human wants and needs. Students in the research were asked if the values associated with a technology are the same or different from those associated with science. Students were reminded that the traditional model of science is simply a

mechanism to aid in understanding the relationship between science and technology. New technologies make possible new scientific processes and developments.

The question of how appropriate the traditional model of science in today's world was also addressed in the research. Students were introduced to stories depicting how scientists have come about discoveries by curiosity or personal interest. The conception of modern science or macroscience encompasses traditional science with societal needs and interests. The technology - science - society trend in science education today is an example of this. Macroscience is often accompanied by science - related questions that touch upon social issues. Much of modern science and technology are associated with societal interests and needs. Society now drives science as opposed to personal needs, interests, and curiosity. Significant society issues arise from and surround macroscience projects.

Integration of Societal Issues Into Science Core Material

When introducing societal issues, ideally, the classroom climate should provide the following elements of experience: role-taking opportunities, intellectual stimulation, responsibility, cognitive - moral conflict, peer interaction and a democratic communicative environment. Along with creating a positive classroom environment, the following questions should also be addressed when attending to the study of controversial issues:

1. *Does the controversial issue support curriculum? Issues that do not have a direct relationship with the knowledge presented in the science course will confuse rather than enhance student learning.*

   For an issue to be used it must be relevant to a specific topic in the curriculum. The intent is to enhance the teaching of the present conventional course topics, not to distract from them.

2. *Are resources available so that the issue can be properly researched?*

   When studying various viewpoints of a particular issue it is important that students have access to appropriate information that covers all viewpoints. This ensures that the issue is multi-sided and controversial.

3. *Can the issue be covered effectively within the time allocated?*

Some issues are complex and multi-dimensional, thus requiring much research and investigation. Issues should be used that can be covered effectively within the specified unit so that it relates to curriculum.

4. *Is the issue relevant to student's daily lives?*

For an issue to be used it should relate to a student's immediate world or a topic that can claim appeal to his or her imagination. Showing how a topic effects a students life or great world issue creates motivation and interest in many students.

During this research, societal issues were made a regular part of the science program. At least one controversial issue was introduced in each unit. Students were prepared for controversy. The methodology for presenting issues included a variety of approaches: interactive debates, role-playing scenarios, oral presentations, written reports and group discussions. These techniques provide an avenue for the enhancement of a wide variety of intellectual skills. Group resolution techniques encourage students to listen to each other and respect the idea the individual is representing.

> *"Conflict resolution skills ensure that students learn to think critically, to reason, to argue logically, to devise answers that are supported by evidence, and to reflect upon their thinking. The development of conflict resolution skills coincides with the development of attitude needed to allow students to broaden and refine their opinions and value commitments" (Ritter, 1992).*

When studying issues students usually begin an egocentric understanding of the issue. In the decision-making process, students are asked to suspend judgement until all of the facts are gathered. In the decision-making process students are involved in:

a) Researching the issue

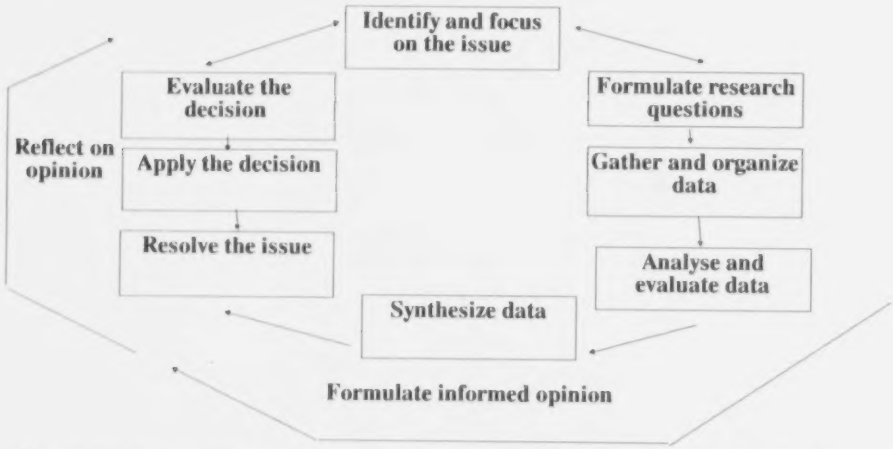
b) Examining divergent perspectives

c) Discussing the issue

d) Personal reflection on the issue

A decision-making model derived by Ritter (1992) was used in the research. The model was based on the following flow chart:

Decision Making Model



Students were involved in using the decision making model to clarify their own values and opinions. Decision-making skills in science curricula provide opportunities for students to interact with their peers and adults regarding science topics that will have a personal impact on them. The changes in science and technology that our students will witness will demand that they have a greater awareness and input into science and public policy issues. Thus, decision-making skills play a vital role in developing socially responsible citizens.

Teaching suggestions that encourage decision-making skills include:

a) Emphasize analytic thinking rather than just the assimilation of theories and positions

b) Focus on issues of human significance with which the student can readily identify

c) Focus on problems that have no easy solutions

d) Focus on viewpoints counter to student viewpoints to force critical thinking about what they and others think.

e) Offer examples or models

f) Relate moral beliefs to the logical bases and underlying world views

g) Avoid indoctrination

h) Stir the imagination with "real life" scenarios and an array of possible outcomes to a moral dilemma

i) Learn to tolerate moral ambiguity *(ie. individuals will disagree)*

j) Encourage ethical decision-making through affective as well as cognitive involvement.

According to Holmes (1991), "*to accept responsibility for ourselves is to be accountable not only for what I intend, but also for what I do and say and what I am like towards others. It means acting reflectively and deliberately, not haphazardly or compulsively or under peer pressure.*" Students must learn to deal with issues in a manner that will foster the development of individual reasoning skills and autonomous reflective thought. "*What is*" and "*What ought to be*" in society are two different questions. Students must learn to make a distinction between the two.

This chapter has addressed the nature of scientific knowledge and the need to integrate societal issues in classroom practice. Students were continually expected to demonstrate an understanding of the processes by which scientific knowledge is developed, and of the interrelationships among science, technology and society.

CHAPTER FOUR
SIGNIFICANCE OF VALUES EDUCATION

Introduction

Education is not value free. Values are intrinsic to the very subject matter we teach. How I teach teaches an ethic. It can model something good, bad or both. Values are inherent not only in what is taught but also in how it is taught. Schools have a tendency to concentrate on teaching facts and concepts and in many cases, have attempted to stay clear of the affective domain. According to the Religious Program in Catholic schools, education is much more than cognitive. "*Education is a process of becoming aware of life's thrust and orientation towards wholeness and completeness. Education awakens in human beings a sense of responsibility towards action that promotes human dignity and solidarity and contributes to individual growth and the on-going transformation of society.*" Catholic schooling thus promotes the complete education of the whole student - the intellectual, aesthetic, emotional, social, physical and spiritual.

Moral Education and Societal Issues

The application of science through technology can give rise to controversial issues. Controversy arises when groups with competing world views draw divergent conclusions about the impact of science and technology on society. One of the objectives of the research was to press students to exercise their critical reasoning skills in assessing complex issues and in doing so to develop their ability to recognize and make value or moral judgements. Making value or moral judgements helps students to become more thoughtful, to think of the interests of others, and to see the ethical implications of their daily lives. This allows for an integration of the knowledge of societal values and the development of positive personal values.

> "*Moral education is accordingly, concerned that students become consistent and responsible adults who care about other people, treat them justly and do something about ethical issues in society*" *(Holmes, 1991).*

We as teachers have a responsibility for encouraging "*standards and examples of behaviour*" which will contribute to the "*well being*" of society. Thus the interrelationship between science and society involves the study of ethics. There is an interconnectiveness between scientific technological issues and their effects on society as a whole. To exclude the study of ethics from science is to offer a curriculum which is solely objective and unrealistic.

> "*To discuss values outside the context of general education would be to reject the most perplexing educational issue of our day - how to assist the rank and file of students in reaching decisions on the complex political, social and moral problems which they will inevitably face. That instruction related values and career preparation must be interfused is all to manifest in the shocking gap which exists between the high occupational competence of many graduates and their low moral concern for the human consequences of their acts*" *(Holmes, 1991).*

Ethics across the curriculum, while still not a reality has become a realistic goal. In the last decade there has been quite an advancement in different fields such as business ethics, environmental ethics, political ethics, professional ethics, sports ethics, research ethics, and so forth. This has helped highly educated scientists, artists, and scholars to deal with and reflect on many of the ethical issues that face them. Scientists are now faced with written and unwritten rules governing the practice in their fields, existing codes of ethics, professional standards and government regulation.

Introducing ethics in science education will not only provide an informative study of social issues, but will enable students to clarify their own views and be able to make informed decisions. Ethical issues and problems need to be addressed because they impinge directly on young people's moral and spiritual development. As educators, we want students to feel in their own way that they have the power to do something about the problems that face humanity.

The development of informed, critical thinking in young people is an integral part of moral development. Whatever the teaching approach "effective science education should help to produce critical thinkers capable of taking action on issues of importance to the human and ecological health of their communities and of the world." (Frazer, 1986).

As teachers, we must be willing to weaken or eliminate rigid subject matter boundaries, pay more attention to the connections among science and technology, and to present the scientific endeavour as a social enterprise that strongly influences human thought and action. A liberally educated person has thinking ability, language and communication skills, decision-making skills, social concern and responsibility, a sense of personal identity, and moral character.

Integration of Science, Technology, Society and Religion

Religious education in Catholic schools is not confined solely to Religion classes; it is dispersed and integrated in all subject matter. Thus religious values are incorporated in all subjects and tied to subject material. Many of the religious values taught are interconnected with societal values and as a consequence can be linked to the study of science. Science is an enterprise comprising knowledge, processes and values. This approach of integrating science, technology, society and religion offers students a holistic approach to studying controversial issues in the classroom.

The Teacher As A Moral Agent

Significant changes in the conception of the teacher's role have emerged many times during recent decades. These changes are partly associated with the new tasks imposed on the school by society. Working in a Catholic school requires teachers to be responsible not only for social and intellectual development but also moral development. Since teachers are given the responsibility to take care of and nurture other persons' development, then teaching can be conceived as a moral enterprise. According to Bergem (1990), children need close relations with adults who can serve as role-models and assist them in their work, learning, and play.

Catholic schooling has developed a basic philosophy regarding its view of humanity, its value systems and what it believes the ultimate goals of education should be. As a consequence of this view, teachers are perceived as role-models for the students. Teachers, should at all times in their everyday work, be aware of the fact that they are role models whose values, attitudes and behaviour have an impact on the development of their students.

According to Catholic philosophy, education awakens in human beings a sense of responsibility towards action that promotes human dignity and solidarity and contributes to individual growth and the on-going transformation of society. By introducing relevant societal issues into classroom curricula, students gain a better understanding of a wide variety of perspectives as well as practice in developing their decision-making skills. Most importantly students can assess certain perspectives based on their value systems and religious upbringing.

CHAPTER FIVE
THE SCIENCE, TECHNOLOGY, SOCIETY MOVEMENT IN THE CLASSROOM

Introduction

Emerging research in science education clearly illustrates that learning science in an STS context results in students with more sophisticated concept mastery and ability to use process skills. *(Yager, 1993)*. All students improve in terms of creativity skills, attitude towards science, use of science concepts and processes in their daily living, and in responsible personal decision-making. This chapter will deal with what STS means, how STS provides direction for achieving scientific and technological literacy for all students, and the role that teachers play in this process.

The Meaning of STS

STS means focusing upon current issues and attempts at their resolution as the best way of preparing students for current and future citizenship roles. The emphasis is on responsible decision-making in the real world of the student. STS provides direction for achieving scientific and technological literacy for all. The emphasis is on responsible decision-making in the real world of the student where science and technology are components. This allows students to instigate, analyze, and apply concepts and processes to real situations. Curricular and instructional processes might consider the following questions:

- Is it a problem or issue?
- How did it become a problem or issue?
- What are some alternative approaches to its solution?
- What are the potential effects of applying the alternatives on individuals and/or society?

STS should help lay the basis for empowering students so that as future citizens they realize they have the power to make changes and the responsibility to do so.

STS: A Way of Producing Scientific and Technological Literacy.

The scientific and technologically literate person has the following characteristics according to Yager:

- uses concepts of science and of technology as well as an informed reflection of ethical values in solving everyday problems and making responsible decisions in everyday life, including work and leisure
- engages in responsible personal and civic actions after weighing the possible consequences of alternative options
- defends decisions and actions using rational arguments based on evidence
- engages in science and technology for the excitement and the explanations they provide
- displays curiosity about and appreciation of the natural and human-made world
- applies scepticism, careful methods, logical reasoning, and creativity in investigating the observable universe
- values scientific research and technological problem solving
- locates, collects, analyzes, and evaluates sources of scientific and technological information and uses these sources in solving problems, making decisions, and taking actions
- distinguishes between scientific and technological evidence and personal opinion and between reliable and unreliable information
- remains open to new evidence and the tentativeness of scientific/technological knowledge
- recognizes that science and technology are human endeavors
- weighs the benefits and burdens of scientific and technological development
- recognizes the strengths and limitations of science and technology for advancing human welfare
- analyzes interactions among science, technology, and society
- connects science and technology to other human endeavors, e.g., history, mathematics, the arts, and the humanities
- considers the political, economic, moral, and ethical aspects of science and technology as they relate to personal and global issues
- offers explanations of natural phenomena which may be tested for their validity

Responsibility of Teachers in STS Education

Teachers have the responsibility to educate children to take their places as participants in society. If we are committed to the view all should participate in the affairs of society, we must educate children to be self-governing decision makers. They must be given the capacities to make decisions for themselves. We, too, have the responsibility to educate students for citizenship. They must learn not to discriminate against others and not to repress viewpoints that may be unpopular. Students must also be educated for reflective choice. They must learn to think for themselves and not be dependent on others. They must have adequate knowledge background to make informed decisions. They must be able to seek out new information and to be able to think critically about the ideas presented to them.

The above responsibilities illustrate the important role teachers play in guiding students towards informed citizenship. Decisions in society stem from the choices and decisions of everyone and not from the pronouncements of a few who are set above others. Students should be made aware of this. Making students aware that they are able to change the state of affairs of society if they take action empowers them. Teachers are thus responsible and committed to the worth and improvement of a democratic society.

STS components are an integral component of senior high science courses in Alberta. According to the Science 10 program of studies, connections among science, technology, and society allow students to perform the following:

a) List for a given instance, appropriate and relevant examples that relate direct scientific evidence to a theory; and describe the limitations of science and technology in answering all questions and solving all problems.

b) List for a given instance, appropriate and relevant examples of technological solutions to practical problems; and describe the functioning of technologies, using scientific principles; and relate the ways in which science and technology advance one another.

c) Identify for a given instance, appropriate and relevant examples that show how science and technology are influenced and supported by society; and describe the responsibility of society through science and technology to protect the environment and use natural resources wisely.

d) Identify subject - related careers and apply the skills and knowledge acquired in Science 10 to everyday life.

SECTION TWO: RESEARCH THEMES

CHAPTER SIX
SCIENCE AND TECHNOLOGY: DEFINING SCIENCE

Introduction

Many students hold misconceptions as to the nature of science and technology. Many of these misconceptions stand in the way of students' decision-making abilities, necessary for a democracy to work. The decisions to be made in the next century call for an informed citizenry. A majority of science teachers depend almost entirely on the textbook for the material and the strategies used for teaching and testing. This, however, does not allow many of the STS issues to surface in many classrooms nor does it create a curriculum that is truly directed towards making students scientifically and technologically literate. Voelker (1981), has stated the problem well by saying:

> *"... if we want a science program that is truly responsive and responsible to the citizen in a scientifically and technologically oriented society, we must elevate current and future citizen concerns. We cannot assume that curricula which emphasize traditional cognitive knowledge and an understanding of the scientific process will lead to an understanding of the science-related issues confronting society. Neither can we assume that such traditional curricula will assist our student-citizens in applying their scientific knowledge and processes to these issues. Some sacred cows of the science curriculum must be eliminated. But the short-term trauma this sacrifice may elicit will be replaced by long-term gains for all citizens. (Voelker, 1981)*

This chapter will address students' conceptions of the nature of science, whether or not they see a relationship between science and society, and finally whether they see any connections between science and religion. The chapter will also address strategies used for refining student conceptions.

Definitions of Science

Definitions of science in literature vary widely depending on an author's perspective and philosophy. High school students, too, express a wide variety of definitions, as shown in Table 1.

Table 1 represents a summary of 53 student responses when asked the question, "*Describe as best as you can what science means to you.*" The table is organized into six major categories. The categories are organized into those most mentioned to those least mentioned and include examples of student responses.

Table 1
Definitions of Science

Category	Percentage Responding	Student Examples
1. Science is a body of knowledge such as principles, laws, and theories, which explain the world around us *(matter, energy, and life).*	30%	• "Science is all facts, rarely is there a chance to have your own opinion. There is little room for imagination. To me, science is straight from the book. There is almost always a right or wrong answer." • "Science is gaining more knowledge of the world we live in, thus helping us to co-exist with a higher level of understanding."
2. Science is exploring the unknown and discovering new things about our world and universe and how and why they work.	28%	• "science involves a connection between man and the unknown; it involves discovery." • "science is discovery and learning; it is the study of how things work and why."
3. Science is finding and using knowledge to make this world a better place to live *(for example: curing diseases, solving environmental problems, and improving our world).*	18%	• "science involves helping us live a better quality of life and living longer." • "science is used quite often in evryone's lives. For instance, it is used by doctors to help sick people with diseases, such as AIDS and MS."
4. Science is carrying out experiments to solve problems of interest about the world around us.	9%	• "science involves performing experiments and gathering information." • "science tries to explain things through experiments and hypotheses."
5. Science is inventing and designing things*(for example: artificial hearts, computers, space vehicles).*	8%	• "science allows us to make technological advances by making devices which accelerate medical research." • "modern inventions have come about by using science."
6. Science is a study of fields such as biology, chemistry, and physics.	7%	• "chemistry, biology, and physics are the three most broad topics in science. Chemistry is the study of atoms, physics the study of energy and biology the study of life. • "To me science is learning about biology, chemistry, and physics."

Percentages for the above table were calculated based on percentage frequency of a particular student definition of science. Many of the students' responses included more than one definition of science. Thus, the total percentage responding represents the sum of the different definitions of science.

Choices 1 and 6 represent definitions which conceptualize science as a body of knowledge. This definition of science received the largest student response. The idea that science is a body of knowledge is consistent with teaching practices that emphasize: (1) getting the right answer, or *(2)* preparing students for external examinations or for post secondary science courses. The definition of science as a body of knowledge, is at odds with most of the professional literature dealing with science education, especially STS science.

Choices 2 and 4 define science more as a process than a body of knowledge. The proportion of expressing this perspective was relatively high. Position 4 describes science as systematic puzzle - solving, a description Kuhn (1970) claims is Position 2 which paints a broader picture of science and was the second most popular response for a definition of science.

According to research by Fleming (1987), students tend to confuse science with technology. Choice 5, a simplistic notion of technology, offers students the chance to reveal such a confusion.

Some students subscribe to a vision of science as something which "*makes the world a better place to live in*", choice 3. This view is known as an "*instrumentalist*" view (ie. science is an instrument of society).

No students viewed science as an organization of people *(called scientists)* who have ideas and techniques for discovering new knowledge. This perspective views science as a social institution. Science is what scientists do, and the doing of science is as much a social process as it is an intellectual process.

> "*Academic science is a social institution devoted to the construction of a rational consensus of opinion over the widest possible field.*" *(Ziman, 1984)*

Thus, one would expect that viewing science as a social institution would be a definition that students would choose, but such was not the case in this research. This data strongly suggests that students have not viewed science as a social endeavour, but instead are holding on to various definitions of science they learned through their study of school science.

When students were asked to reassess their definitions of science in November, 1993, after the study of five controversial issues, only 19% made additions or revisions to their answers. The following quotations summarize student responses:

- " science is constantly being revised; theories are always being changed because of new developments "
- " science involves many areas of expertise and other subject areas "
- " there are many jobs and technologies related to science "

From the 19% if students who made additions, three major areas were identified:

1. The tentativeness of science; this corresponds to the nature of science.
2. The view of science as a social institution involving an organization of people working in different areas of science who have ideas and techniques for discovering new knowledge.
3. The integration of science with other subject areas or disciplines *(ie: social studies, religion).*

Science and Society

An integration of science and societal issues was a integral part of the research. Table 2 represents a summary of 53 student responses when asked the question " *Does the study of science relate to society? Explain why or why not.* " 94% of the students responded yes; 4% responded no, and 2% had no response.

Student responses to the question of why science is related to society can be summarized into five major categories. The categories are organized into those most mentioned to those least mentioned and include examples of student responses.

Table 2

Relationship Between Science and Society

Category	Percentage Responding	Student Examples
1. Society uses science everyday.	44%	• "we need and use science everyday. We (society) are a part of science. The need for science is used in practically everything we do, like when you build a house, you need to put wiring in it for elecricity. When you cook and egg, it is chemically changed. From planting a flower to making ice tea we use science." • "we use science continuously in our everyday lives, often without realizing it."
2. New discoveries in science effect society in positive and negative ways.	25%	• "scientific discoveries attempt to better society and help make life easier; but in many ways society has created many political and economical problems pertaining to waste and natural resources, as well as other environmental problems." • "technology can effect society in positive and negative ways."
3. Science has offered society new technologies that have improved lifestyles.	15%	• "as science increases technology it changes our lifestyles. Scientific advances make life easier and sometimes better." • "modern day conveniences have all been made possible through science. We have gone from our cave-man days to a world full of televisions, phones, and radios."
4. Many individuals in society have jobs related to science.	13%	• "many people in society have jobs that are related to science in some way." • "a lot of occupations have relations with the sciences, such as teachers and biologists."
5. New technologies in science have created ethical dilemmas.	3%	• "new technology may or may not agree with certain peoples ethics. Several opinions are formed by certain issues (ie: abortion, environmental problems)." • "science has presented society with a variety of dilemmas: which medicines are safe? should we protect wildlife and trees? how can we prevent the greenhouse effect?

The majority of students (94%) identified a relationship between science and society, however, many students had difficulty in articulating this interrelationship. Only 3% of the students identified ethical or moral dilemmas related to the scientific enterprise.

When students were asked to reassess their answers to the question, *"Is there a relationship between science and society"*, the original 4% who responded *"no"* changed their responses to *"yes."* Those students who did not give a response to the question, continued to give *"no"* response in November, 1993.

A total of 12% of the students changed and made additions to their responses. Listed below is a summary of the responses which were diverse from the original five categories.

1. Society sets guidelines for science and in a sense controls what science does. Society influences decisions made in science.

2. Many ethical dilemmas arise from science ie: cloning. particle accelerators, environmental problems, etc. which require society to make difficult decisions.

Science and Religion

The philosophy of Catholic schooling involves the integration of religion into all subject matter. Thus, many religious values are consistently being incorporated into core subjects either implicitly or explicitly. There has been a grave misconception in society that religion and science are two different identities which are antagonist to one another.

The antagonisms between science and religion *(i.e., the church)* seem to have began during the early part of the 16th Century, along with the development of science itself *(Barman, Rusch, Cooney, 1981)*. The classic case of Galileo's difficulties with the church of his day resulted primarily from the belief of church leaders that Galileo's alternative explanations of certain scientific phenomena challenged the authority of the church. The church had come to serve as the repository for much of all knowledge during Medieval times. *(Butterfield, 1965)*. The development of the Renaissance, of which the sciences were an important component, was also viewed by the church as a turning away from God and the things of the spirit, and a concentration on the physical world. Another serious religious controversy occurred with the

publication of Charles Darwin's book, The Origin of Species. Here the controversy centered on the questions which Darwin's book and ideas raised concerning the old classical interpretation of the Bible. The notion that man may not have been created along with the rest of the universe in the manner described in Genesis brought about a strong response by many people. This controversy, in effect, still persists today.

In Catholic education there is the integration of evolutionary theories with religious teachings about the creation of the world. This conflict over science and religion is sometimes very difficult to overcome. To what extent does a conflict over science and religion seem to be present in the minds of students?

In the research, 53 students were asked to respond to the question, "Is there a connection between science and religion? Explain why or why not. " 52% of the students responded no; 38% of the students responded yes; and 10% of students were not sure. Student responses to the question are summarized in Table 3.

Table 3
Relationship Between Science and Religion

Students who responded yes to the question of whether there is a connection between science and religion.	Students who responded no to the question of whether there is a connection between science and religion.
° man's actions are affected by religion ° both science and religion explain the beginning of life ° God created all living things and science is about the study of living things ° science has helped discover religion (ie. scripture) ° evolution can be explained by science and religion ° religion can explain many phenomena which cannot be explained by the scientific community ° both science and religion are needed to explain our existence on earth ° God created the world and in science we study this world. We are studying all that God has given us.	° science deals solely with factual information, whereas religion deals with faith.

When students were asked to reassess their answers to the question, "*Is there a connection between science and religion?*", the majority of the original 52% who responded "*no*" changed their responses to "*yes*". In November, 1993, a total of 34% of the students responded yes to the question, 7% responded no and 59% made no changes from the original response.

The following is a summary of the statements made by students who changed their response from seeing no connection between science and religion to seeing a relationship between the two.

° The study of ethics (religion) is a very integral part of science. *(examples include Biotechnology)*

- religion sets ethical guidelines for us to be able to do research in science
- our religious values are often in conflict with science (examples include cloning of human embryos)
- many people feel science is becoming too complex and in many instances scientists "are playing God".

The integration of science and religious perspectives, at times, had a profound influence on a students' viewpoint of a particular societal issue. Many students were often unaware of what and why their faith had particular views about specific technologies. The Christian tradition has held distinctive views about human fulfilment and human nature which are relevant to judgement about applied science and technology and the institutions which control them (Gosling and Musschenga, 1985). Studying controversial issues has allowed the students to examine several divergent viewpoints including their own faith perspective. There need not be a conflict or dualism between science and religion. "*Religious faith can lead the science teacher to convey to students a sense of the limitations of science and humility concerning the tentative and selective character of its concepts and theories.*" (Gosling and Musschenga, 1985).

Knowledge is holistic in nature and the values implicit in religious studies can extend to science and technology.

> "*Pupils should develop their knowledge and understanding of the ways in which scientific ideas change through time and how the nature of these ideas and the uses to which they are put are affected by the social, moral, spiritual and cultural contexts in which they are developed.*" *(Poole, 1990)*

The study of controversial issues allowed students to see science within a larger framework. The integration of their own faith perspective with the issues being discussed allowed students to gain a greater understanding of why their faith had distinctive views regarding particular societal issues in relation to science.

Strategies for Restructuring Student Conceptions

Strategies involved in changing student conceptions often involve using a diversity of teaching strategies as well as creating an appropriate and effective ethos in the classroom. Often as teachers, we feel restricted and thus rely only on traditional approaches.

The following summarizes some resources and teaching approaches that can be used in discussing controversial issues.

1. Teachers look beyond the boundaries of a textbook or curriculum guide and introduce controversial issues at relevant points of the curriculum.
2. Teachers are seen as learners themselves and as facilitators and collaborators in student learning versus dispensers of information.
3. Teachers use a variety of teaching strategies such as community services for information, expertise, ideas, and materials.
4. Teachers working with other staff members in other disciplines in order to develop holistic understanding and provide linkages between subject areas.

Teaching in an STS classroom involves both students and teachers working cooperatively together, or from suggestions offered by students alone based on their personal experience. Throughout the research students often made their own choices in the topics they wished to research, the method of presentation and the delivery of scientific information. Student experiences, newspapers, journals, magazines, radio and television programs, the library, interviewing individuals, textbooks, and local, national, or international debates/issues are common sources used in creating investigations designed to solve real-life problems. The students must take ownership of the topic for them to be enthusiastic in carrying out the investigations. This likely occurs if they see relevance of the topic to their everyday lives, or if they can convince themselves of the rationale for the investigation.

After agreement on the topics, students either individually or in groups plan their investigations accordingly. The planning involves many process skills such as designing appropriate procedures for investigations, identifying the sources of necessary equipment/materials/contacts and decision making skills.

Common strategies employed in traditional classroom teaching of science include lecturing, questioning, describing, explaining, outlining and illustrating on the chalkboard, demonstrating, and directing students to sources of information during lessons or to textbooks for homework. All these activities are executed by the teacher. In STS teaching, students are directly involved in practical, problem solving activities and are encouraged to verbalize their thoughts by asking questions or by finding the answers to questions on their own. Thus, this involves student action versus teacher action. In traditional teaching students were rarely involved in decision making because teachers made all decisions and basically directed all activities.

The variety of approaches that can be used in studying societal issues include case studies, simulations, role-playing, debates, library searches, brainstorming, panel discussions, individual or group projects, problem solving, decision making, class discussions and presentations, displays, designing experiments, letter writing, invited guest lecturing, field experiences, and laboratory activities. Through these strategies, students come to acquire and use the processes of science which are appropriate to the solution of particular problems and become better informed on science/society/technology issues affecting them and society as a whole. Thus students become more scientifically literate and are able to take personal action as citizens living in a democratic society.

CHAPTER SEVEN
STUDENT INTERVIEWS

Introduction

Fifty three student interviews were conducted at the end of the research. The duration of the interviews varied from 10 to 15 minutes, depending on the depth of explanation given by students and my ability to conceptualize and record what students were saying. This chapter describes the results of eight categories addressed in the interview and relates general conclusions based on percentages of student responses and responses given by students.

Portfolio Work on Controversial Issues

Portfolio work was an integral part of the Science 10 program. Students were responsible for placing all work on controversial issues in their portfolio and adding additional information from sources such as telecasts, newspapers, journals or magazines. The majority of students enjoyed the portfolio work and gained more insight and knowledge about societal issues. Table 4 summarizes the answers given by students in the interview regarding their portfolios.

Table 4
Portfolio Work on Controversial Issues

Question	Student Responses
1. Did you enjoy the portfolio work on societal issues?	Yes: 81% No: 19%
2. Did you gain more insight and knowledge about societal issues by doing the portfolio?	Yes: 94% No: 6%
3. Has portfolio work been done in other science classes?	Yes: 3% No: 97%

When students were asked why they enjoyed portfolio work, these were some of their responses:

- " I liked the idea that 10% of my mark was based on portfolio work because there was less emphasis on examinations".
- " I enjoyed doing portfolio work because it gave me the opportunity to be creative".
- " I enjoyed doing portfolio work. I've never done it before".
- " Portfolio work encouraged me to read the newspaper - something I don't often do".

Relationship Between Science and Society

During the interview students were asked the question, "Do you see a relationship between science and society?". Students were also asked to explain their reasons why or why not. Table 5 summarizes student responses and gives examples of student answers.

Table 5
Questions On The Relationship Between Science and Society

Question: *Do you see a relationship between science and society? Explain.*

Student Response:

Yes 97%
No 3%

Student Examples:

		Percentage Responding
I.	The issues and knowledge acquired in science can be applied and are relevant to everyday life.	44%
II.	Science can change society by creating technology.	27%
III.	Science provides society with knowledge and theories.	11%
IV.	Science provides answers to questions which have more than one answer for society.	7%
V.	Society dictates what science should be doing and lays down guidelines and ethics for scientists.	7%
VI.	Science provides society with occupations for the present and future.	4%

Question: *How would you rate the importance of relating science to what's happening in society?*

Student Response:

Extremely Important	34%
Very Important	49%
Important	17%
Somewhat Important	0%
Not Important	0%

Question: *Did you enjoy studying controversial issues this year?*

Student Response:

Yes	90%
No	3%
Sometimes	7%

Question: *Has the study of controversial issues helped you to understand the relationship between science and society?*

Student Response:

Yes	100%
No	0%

Newspaper Reading

Many of the controversial issues which plague our society today are continually addressed in daily newspapers. Students were asked whether they read the newspaper on a regular basis to inform themselves of societal issues. They were also asked to indicate how often they read about science related controversial issues in the newspaper. The responses are summarized in Table 6.

Table 6
Frequency in Reading The Daily Newspaper

Yes 38%

- Everyday 25%
- Once a Week 7%
- Weekends Only 3%
- Every two Weeks 3%

No 62%

Science and Religion

Students were asked whether religion and religious values had been incorporated in other science classes. The responses were as follows:

28% *responded yes*

62% *responded no*

10% *responded sometimes*

Scientific Literacy

One of the objectives involved in introducing societal and controversial issues is to increase scientific literacy amongst students. Students were asked in the interview to explain what is meant by a scientifically literate individual. Their responses are summarized in Table 7.

Table 7
Definitions of Scientific Literacy

Scientific literacy means:	Percentage Responses
I. Attaining knowledge about science.	37%
II. Understanding the process of science *(ie. Scientific method)*.	30%
III. Being able to use science in your life *(ie. Application of science in everyday life)*.	10%
IV. Knowledge of different disciplines of science.	8%
V. Relating science to the work place.	3%
VI. Understanding science as a whole; not just parts.	3%
VII. Having a grasp of scientific issues and technology.	3%
VIII. Understanding various viewpoints when analyzing scientific data.	3%
IX. Understanding the relationship between science and society.	

Differences in Science from Other Subject Areas

In the interview process students were asked the question, "How is science different from other subjects?" Students were asked to comment about the differences in teaching strategies and learning activities. Student responses are summarized in Table 8.

Table 8
Differences in Science from Other Subject Areas

I.	Science Involves Hands on Activities *(ie. experiments)*.	35%	
II.	Science Classes Discuss Relevant Societal Issues.	29%	
III.	Science involves more discussions.	13%	
IV.	More research is involved in Science.	5%	
V.	The science classroom environment is creative and not restricting.		5%
VI.	More written notes in science.		5%
VII.	Science offers a variety of learning experiences.	2%	
VIII.	There is a thematic approach in studying science.	2%	
IX.	Science involves many viewpoints/perspectives *(including Catholic perspective)*.	2%	
X.	Science involves studying about various careers.	2%	

Work on Controversial Issues in Other Science Classes and Types of Issues Discussed

Students in the interview were asked to respond to the questions, "Have you ever discussed controversial issues in relation to science and society in other science classes?, and What types of issues have you discussed?" Student responses are summarized in Table 9.

Table 9
Controversial Issues Discussed in other Science Classes

Question	
Have you ever discussed controversial issues in relation to science and society in other science classes?	
Student Responses	
YES 69% NO 31%	
What types of issues have you discussed?	
I. Water and air pollution.	23%
II. Water and Sewage Treatment plants.	23%
III. Deforestation.	13%
IV. Greenhouse Effect.	13%
V. Chemical/Radioactive Waste.	10%
VI. Environmental Issues.	6%
VII. Water conservation.	6%
VIII. Abortion.	3%
IX. Endangered Species.	3%

The majority of students only listed one or two controversial issues discussed in other science classes. Only 7% of the students listed three controversial issues discussed in other science classes. No students gave more than three responses to the question.

Students also mentioned that the controversial issue of sewage and water treatment was dealt with on a fieldtrip to Edmonton's water and sewage treatment plant.

Types of Activities in Discussing Controversial Issues in Other Science Classes

In the interview process students were asked to list the types of activities done in other science classes with regard to science/societal issues. The results are summarized in Table 10.

Table 10
Activities Used in Discussing Controversial Issues in Other Classes

Type of Activity		Student Responses	
		YES	NO
I.	Role Playing	40%	60%
II.	Debates	93%	7%
III.	Experiments	100%	0%
IV.	Discussion of Societal Issues	79%	21%
V.	Oral Reports on Controversial Issues	41%	59%
VI.	Guest Speakers on Controversial Issues	10%	90%

Gender Differences

When examining the differences in the interview, no significant differences were observed. The girls, however,*(100%)* enjoyed the work on portfolios; whereas some of the boys did not. Girls spent more time collecting newspaper articles and perfecting their portfolios.

SECTION THREE: Interpretations

CHAPTER EIGHT
RESEARCH OUTCOMES

Introduction

The introduction of controversial issues presented opportunities for students to carefully consider relevant, real world problems. The issues enhanced topics in the Science 10 program by highlighting their connection to science and the natural world. This chapter will address some of my personal reflections regarding the research, the problems encountered with values education and the relationship students discovered about science and society as well as science and religion.

Personal Reflections on the Research

In this research ethical and moral discussions were broadly defined. Students were given choices and current controversial issues emerged as the research proceeded due to current events that were described in the daily news. By becoming an integral part of the science curriculum these discussions contributed to overall course objectives as well as bringing new objectives to the learning situation. Using controversial issues enables students to develop listening skills, oral communication skills, and the ability to participate constructively in group discussions. Student groups were rotated enabling students to interact with a variety of individuals. Properly conducted moral discussions create classroom dialogue which focuses on the substance of student remarks, the acceptance of statements and points of view as given, and the treatment of each other and each other's ideas with respect. Most students found the study of controversial issues interesting and exciting, and looked forward to these discussions in class. Many of the students commented that they enjoyed the array and variety of activities versus the notion of always listening to the teacher. Hence, school seemed more interesting and relevant to them.

As a teacher introducing controversial issues, it was important to establish a non-judgmental classroom climate that reflects trust, informality, and tolerance. Students were

encouraged to exchange ideas and to interact; to treat the ideas and points of view of others in respectful ways.

Moral dilemmas are problematic in nature in that there is no single obvious right answer. Life in out society abounds with moral dilemmas and therefore it is important that students have the decision-making skills to cope with the many problems society now faces. Introducing controversial issues that plague society gives students the opportunity to begin to think reflectively about problems that they will encounter in both their personal and social lives. Weighing the benefits and risks of a particular dilemma or problem is a critical and important life skill.

School and Society : Barriers to Values Education

Now that controversial issues and questions of morality abound in our society, what are some of the existing barriers - social, political, cultural, and institutional to the goals and outcomes of values education? Schools are one part of a larger set of organizations, institutions, and processes that facilitate the development of children within the society. An analysis of the school as a source for values instruction suggests that attention needs to be directed not only toward the dimensions of the developing student, but also toward the processes occurring within the school as an organization, and the nature of the society of which the school and the students are part (Silver, 1976). These three elements - student, school, and society - when considered both separately and interdependently, provide a tangled web of values, theoretical concepts and empirical data.

> ..."*schools are partly a reproduction, partly a reinforcement, of the social and economic structure of society at large. The process of schooling is a way of getting acquainted with general social patterns, even to the point of internalizing them.*" *(Silver, 1976)*

The decisions students make regarding controversial issues, were based on scientific knowledge and research, and most importantly, their own ability to evaluate a situation. Their evaluation, at times, did not necessarily center on the values of the society of which they were a part. It was important for me as a teacher to reinforce the notion that no particular point of

view was right or wrong. Students were evaluated on their ability to collect information, analyze a variety of viewpoints and make decisions based on their research. Decisions made by students were not always in accordance to those values chosen by society at large.

Students were continually asked to reflect on the political nature involved in decision making by society. Often they found that certain segments in society had more control and power, and as a consequence dominated the decisions made by the whole of society. An awareness of the political, social, cultural, and economical forces made the task of decision-making on behalf of the students, much more difficult.

A second barrier involved in introducing societal or controversial issues was the time-factor. Many of the science programs are dramatically content orientated and often their is little time in using appropriate controversial issues on a continual basis in the classroom. Organization was a key component in this research. A persistent question arising in my mind was, "How am I going to teach all the required curricula and at the same time introduce relevant societal issues in the time frame allotted?"

There are several ways I addressed the latter question. Firstly, there was the realization that only a set number of controversial issues could be discussed in the allotted time frame. Generally, two issues were discussed per unit. Secondly, students were informed in advance that we would be studying certain issues so they would have sufficient time to research their topics and gather information. Classroom time was also structured so students would have time to communicate with fellow students regarding project work as well as time to update their portfolios and share information. Thirdly, students were expected to participate actively in their own learning and assume increased responsibility for their learning as they studied controversial issues related to core material. As a teacher, I acted more as a facilitator of learning rather than directing students in a rigid and step-by-step manner. Students were free to chose their method of presenting the issues and were encouraged to use their own creative talents.

Discovering Interconnections Between Religious Faith and Science

Many students were also amazingly surprised as to how their Catholic faith, in many instances, was in opposition to the values and decisions made in society. A tensionality developed in many students - are the connections and values between religion and science that diverse? Are these two disciplines not connected in an intrinsically unique way? Many of the students came to realize that the ethical questions posed by each discipline were not all that diverse, but surprisingly the same.

According to the document "*Congregation for the Doctrine of Faith*", (Vatican City, 1987) the teaching of the Catholic church calls humanity to appreciate the inestimable value of what has been given by God and to take responsibility for it. This fundamental principle must be placed at the centre of one's reflection in order to clarify and solve the moral problems raised by scientific interventions on life and on our planet. This notion of responsibility towards humanity and earth is closely associated with the environmental problems our society faces today.

The doctrine written by the Catholic Church reminds us that with the progress of biological and medical sciences, man has acquired new powers, with unforeseeable consequences. These powers may constitute progress in the service of man but they may also involve serious risks. Students were asked to reflect on the benefits and risks of particular issues as well as ponder on the question of which moral criteria must be applied in order to clarify the problems posed today in the field of science. The controversial topic of "*cloning human embryos*" came at an optimal moment in the research. As students were collecting their data many newspaper, radio and television broadcasts were discussing laws needed in the areas of reproductive technologies in Canada to eliminate risks involved with the technologies.

Students involved in the research were asked to also include the Catholic perspective when analyzing data and making conclusions. This provided students the opportunity to integrate their religious faith with the study of science to be able to see the linkages between

the two disciplines. At times, many students did not agree with what their faith perspective was regarding particular issues. On the other hand many students began to realize that their religious faith had guidelines and reflective questions on how to tackle various ethical issues.

Discovering Interconnections Between Science and Society

The majority of students (94%) identified a relationship between science and society. However, very few students articulated the ethical dilemmas that arise from science which require society to make difficult decisions. During the latter portion of the research when students were individually interviewed, an additional 7% of the students identified a relationship between science and society. At this point, more students (7%), in comparison to the beginning of the study, identified the ethical nature of a scientist's job.

CHAPTER NINE
IMPLICATIONS FOR TEACHERS

Introduction

In Alberta we have entered an era of "new curriculum" for science education. Changes were inevitable in order to truly reform science education for students of the 21st century. Although most science teachers agree that STS should be part of every science course, there has been little change in the topics we are teaching, our methods of teaching these topics, and assessing students. This chapter will address particular questions and concerns facing teachers and offer suggestions for changes that can be incorporated when teaching scientific issues.

The Need for Change

Science is becoming increasingly more complex and as our society makes technological advances, it is no longer plausible to teach scientific concepts as objective truths. In many instances, science involves questions of values and ethics - and thus students are continually involved in decision making and analyses.

> *"It has been said that science has no ethical basis, that it is no more than a cold, impersonal way of arriving at the objective truth about natural phenomena. If we critically examine the nature, origins, and methods of science we may logically arrive at the conclusion that science is ineluctably involved in questions of values, is inescapably committed to standards of right and wrong, and unavoidably moves in the large towards social aims." (Glass, 1965)*

Educators entering the 21st century realize that changes are needed but it is more difficult to suggest what those changes should be. How can we truly reform science education? There are no simple correct answers, but we can reflect and question our philosophical basis as to what constitutes a basic science education.

Challenges for the Future and Questions For Reflection

Whatever our mind set is as teachers, in order to change we must overcome the habits of the past. Seeking a new direction involves commitment and the willingness to try new techniques and approaches.

Before we can arrive at a philosophical basis as to what constitutes a basic science education specific questions need to be addressed:

1. What is the purpose of curricula? Should a curriculum be designed to provide students opportunities to enhance their abilities to think, communicate, participate responsibly in society, understand themselves and others, and to "learn how to learn"? Are our current courses designed this way?

2. Is it important to integrate values into all aspects of the curriculum? Do we teach, by example or otherwise, the values of Canadian society? Which values are these?

3. Is the purpose of education to teach students to be self-evaluative and self correcting? If it is, are we teaching in a way that fosters this aim?

4. What relationships between science, technology, and societal issues must be understood to be "literate"? For example, do students need to know about the nature of science and technology or just how scientific ideas and technological devices impinge on society?

5. Should we allow diploma exam questions to become the curriculum? To what extent do teachers teach to the test, and if we do, is this an acceptable practice?

6. Should we allow the textbooks to become the course? As teachers, have we been conditioned to cover certain pages in the text?

There always has been and certainly will continue to be questions regarding what constitutes a basic education in science. But, as teachers, we need to collaborate and engage in open discussion as to what constitutes a well-rounded curriculum in science and one which prepares students for the 21st century.

Suggestions For Change

Teaching is truly an art in the sense that we are continually modifying and improving our teaching methods for the benefit of our students. From my research on controversial issues there are eleven suggestions that come to mind:

1. As teachers, we must try to diminish our focus on content and stress the ideas that we know are important to the understanding of science.

2. Teachers are truly able to determine what is best for students since they ultimately see them on an everyday basis. Thus we should not be afraid to try different approaches and activities. Every class has its own unique group of students with very individual learning styles. Teachers can choose controversial issues which are relevant to curriculum and at the same time meaningful and interesting to students.

3. As teachers, we can integrate into our classrooms values that would make our society a better place. Students can be challenged to address the question, "What values are important to our Canadian society?"

4. As teachers, we should try not to be limited by diploma examinations or textbooks. These provide only a limited framework in terms of the direction of the course. Teachers can provide innovative strategies and approaches that are often not found in textbooks. Teaching towards a diploma examination often focusses on cognitive and objective knowledge. Students are thus not involved in decision making skills or current societal problems.

5. As teachers, we must allow for flexibility. Often current controversial issues arise in daily news; if these issues are relevant to the curriculum they can be incorporated and provide students with another dimension of learning.

6. As teachers, we can consistently try to make the material we are teaching relevant to everyday life and society. This provides students with the opportunity to carefully consider and study relevant, real-world problems.

7. As teachers, we can encourage a diversity of teaching approaches and strategies. This allows us to present information in accordance to a variety of learning styles.

8. As teachers, we can share our knowledge and ideas with others in our profession. Teachers often isolate themselves in their classrooms. If a particular teaching strategy is successful, we should talk about it and share the idea with other colleagues.

9. As teachers, we should encourage skills in listening, decision-making, and a respect for the opinions of others.

10. As teachers, we should continue to strive for continual professional development in our subject area. Professional development can often increase our enthusiasm and revitalize our teaching methods and skills.

11. As teachers, we can continually utilize the help of community members, experts and guests to facilitate the learning process so that students can gain a broader perspective and additional information on particular scientific issues.

Chapter Ten
Considerations For Further Research

Introduction

Most science units we teach collide with life outside the laboratory and classroom. We are consistently confronted with issues involving moral and ethical dilemmas. The physical sciences are generating technology that transforms our world faster than most educated citizens can comprehend. The decisions our students must make about what to do with the consequences of new scientific discoveries are difficult and require critical thought. Strategies for engaging science students in the analysis of issues are not well established in science teaching primarily due to the fact that program of studies are highly content oriented. This chapter will address some critical questions that need to be considered if controversial issues are to be integrated in science teaching.

Questions That Can Be Adressed For Further Research

Several questions need to be addressed if controversial issues are to be incorporated into science curricula. Some of the questions include the following:

1. What do teachers consider to be a "balanced curriculum"? One which allows students to acquire various skills not just cognitive knowledge? One which develops the cognitive, spiritual, aesthetic and social dimensions of the individual?
2. How can teachers collaborate to include relevant societal issues in their courses?
3. How do teachers feel about going beyond the curriculum and incorporating questions of values and ethics? Is this part of our role as teachers?
4. Can the introduction of societal and ethical issues be incorporated into all subject areas? Would teachers be willing to work with teachers in other subject areas to develop strategies in incorporating controversial issues?
5. If questions regarding controversial issues were included in departmental examinations, would more teachers be inclined to introduce and research them in their classrooms?

6. If students were continually confronted with controversial issues and involved in decision making skills, would this better equip students to deal with the many decisions they will face in their lives?

These are just a few of the questions which come to mind when addressing the question of whether controversial issues should be introduced into science curricula.

Conclusions

This research project has allowed me to focus and reflect on the question of what it means to be a teacher. It has allowed me to put into action my own ideas and philosophy as to what comprises a well-rounded science education. Science has never been neutral or value-free. This study has allowed students to see the findings of science within a larger framework. By introducing societal issues science becomes both personally meaningful and as a consequence relevant to their daily lives. Any science curriculum should have, in addition to science content and science process skills, goals related to the cultural implications of science and the nature of the scientific enterprise.

The addition of values related objectives during this research enhanced motivation and critical thinking among the students involved. When studying the controversial issues, students had the opportunity to discuss new information, to listen to others, analyze consequences, make decisions and have their logic criticized by their peers. This type of social interaction creates a highly motivated and interactive learning environment. Students began to realize quickly that their own options were rather useless when trying to defend a particular perspective. Studying controversial issues using a variety of teaching strategies such as role-playing, debates, drama, guest speakers, film, video, discussions, newspaper articles, case studies, and school and community services provided a more interesting learning environment - one which was not restricted to a particular learning style.

Another dimension of the research was to incorporate the philosophy of educating the "*total*" person - the intellectual, the physical, social and religious. The religious dimension played an important part in the study. As Catholic educators we try to bridge the gap that exists between science and religion. Christian values are continually incorporated into all subject curricula. The values include the following:

a) Respect for human dignity. This includes sensitivity to the effects of technology on people.

b) Active response to the neighbour in need. Applied science is largely determined by the interests of industry and political goals of governments.

c) Modesty and sustainability. This includes avoidance of life-styles with the compulsion to consume. It also involves responsible stewardship and environmental preservation for the present and future generations.

d) Cooperation and working together. This involves collaborating and working together in decision-making.

e) Respect for nature and that a unity exists between nature and humanity. This involves increasing our awareness and concern over the long term effects of ecological insensitivity.

The above Christian values were continually incorporated in studying the ethical issues involved. Catholic schools attempt to integrate issues which relate to moral and social education, to affective education, to the living of values and to the development of a moral conscience. In the research, there was an integration of ethical issues at relevant points of the curriculum.

Values education was involved in the research when attempting to relate science to society. The term values education, however, has different meanings for different people. Values education in the research did not involve instilling specific values into students, rather it involves a process in which students examine their beliefs and formulate their own judgements on specific issues. Students were encouraged to view themselves as personal social interactive beings, not fully autonomous but members of a community or social system.

Incorporating controversial issues encouraged students to use logical thinking and scientific investigation to decide values and questions. It encouraged students to use rational, analytical processes in interrelating and conceptualizing their values. When introducing issues structured rational discussions demanded the application of reasons as well as evidence, testing principles, analyzing analogous cases, debating and research.

There were several steps used in the actual planning of a value-laden issue. They are summarized as follows:

1. **Integration:** Analyze each unit or chapter that you plan to teach for ideas which might be appropriate for developing a values lesson which fits the materials in the chapter. For example, an earth science chapter on rivers and streams would provide the context for values lessons on human choices related to building homes on flood plains, and the channelization of streams and its consequences. A biology unit on Botany may provide a good basis for discussing food production, the "*green revolution*" and world hunger.

2. **Student Input:** Get input from your students regarding areas of social concern which they might like to investigate in class. Often, students have very good suggestions for discussion topics, and may even be able to help you in the planning and resource gathering for the lesson.

3. **Teaching Strategy:** Select the appropriate values education approach for each individual lesson. If the main purpose of your lesson is to clarify existing student values, if it is to initiate student action on a problem, of if it is to analyze an issue, you will need to make decisions to use strategies which are appropriate to your objectives.

4. **Notes for Future Reference:** During the lesson itself, keep some notes of issues that are raised along with the main issue, make careful observations of student reactions, and generally evaluate the effectiveness of the lesson. Keeping track of lessons in this manner can allow you to develop spin-off lessons, and to make modifications in your original lesson more easily.

As educators incorporating controversial issues it is important to analyze our conceptions of science education. Different models of science reflect different views of the nature and methods of science. We may wish to view science solely as theory, as a creative process or ultimately as a social activity. Incorporating controversial and value laden issues views science as very much a social activity.

Incorporating values and issues allows us to do the following:

a) To realize that the decisions that scientists and society make regarding scientific knowledge and technology are not value free.

b) Create an awareness that the impact of science and technology is not always beneficial.

c) To focus on other domains of knowledge (ie. affective, social, and spiritual)

d) Promote student use of scientific knowledge and skills in personal and social life.

e) Bridge the gap between religion and science.

f) Encourage students to practice decision making skills and justify their views based on long term consequences.

The teaching of controversial issues as a teacher has allowed me to focus on the social dimension of science. In the past, I have often focused on teaching the facts and restricting myself to textbooks and prescribed curricula. This has created an uneasiness with me because it creates a very narrow minded approach to teaching and presenting science. Actively involving students in decision-making and teaching strategies creates a classroom environment where students are allowed to respond freely and openly. The classroom dynamics becomes diverse and interesting. Students begin to find relevancy in their school work and take pride in their research and accomplishments. The learning becomes active rather than passive.

Allowing students to study issues provided an abundance of collaborative group work. Students were encouraged to work together cooperatively. A cooperative attitude is needed among people if world problems are to be solved. This is something we often forget as teachers. Group work can be very positive if students are on task and have specific objectives to accomplish.

Science education today is more directed at public scientific literacy than every before. Part of this literacy ought to include an understanding of the values systems which characterizes work in science. We live in a culture which has developed certain ways of solving problems an acting. We need to analyze our old ways and make adjustments where necessary. Students must

be given the confidence and skills to examine the "norm" and make changes, as a society, if necessary. Values education can provide students with the skills necessary to do so because it is an education that helps form the conscience and develops good decision-making skills. As Albert Einstein has so diligently stated:

> *"It is essential that the student acquire an understanding of and a lively feeling for values. He must acquire a vivid sense of the beautiful and the morally good. Otherwise he - with his specialized knowledge - more closely resembles a well-trained dog than a harmoniously developed person." (Holmes, 1991)*

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Appendix

Environmental Survey

1. I try to be aware of the effects of my actions on the environment and to minimize them.

   ☐ a) Yes

   ☐ b) No

2. When I stop my car, I turn off the motor.

   ☐ a) Right away

   ☐ b) Not at all

   ☐ c) If I have to wait more than 5 minutes

3. When I have an errand to do that's less than a kilometre in distance I travel

   ☐ a) on foot or bicycle

   ☐ b) in my car

4. I travel to work

   ☐ a) on foot or bicycle

   ☐ b) alone in my car

   ☐ c) on public transit

   ☐ d) with others in a car (theirs or mine)

5. For recreation I

   ☐ a) do not use skidoos, trail bikes, or motorboats

   ☐ b) do use these items

6. I forget leftover food in my refrigerator

   ☐ a) never

   ☐ b) often

   ☐ c) rarely

7. I take my own coffee mug to work instead of using disposable cups each day

☐ a) yes

☐ b) no

8. I use electric toothbrushes, can openers, and knives

☐ a) never

☐ b) often

☐ c) occasionally

9. I return beverage cans and bottles to recycling depots

☐ a) always

☐ b) often

☐ c) from time to time

10. I am careful to turn taps off and ensure that taps don't drip and toilet tanks don't leak

☐ a) yes

☐ b) no

11. During winter I set my thermostat

☐ a) less than 19°C during the day and lower at night

☐ b) high all the time

☐ c) high during the day, a little lower at night

12. I save newspapers and glass bottles and take them to a recycling depot

☐ a) both newspapers and glass

☐ b) neither

☐ c) one or the other

13. I use the blank sides of printed sheets as scratch pads

☐ a) yes

☐ b) no

14. I reuse paper bags and plastic containers

☐ a) yes

☐ b) no

15. I take my own bags to the grocery store to carry home my groceries

☐ a) yes

☐ b) no

16. I grow at least some of the fresh vegetables I serve

☐ a) yes

☐ b) no

17. I have written a letter to a minister, MP, MLA, or city politician about an environmental problem

☐ a) yes

☐ b) no

18. I have written a letter to a newspaper supporting public transit, parks, or environmental protection

☐ a) yes

☐ b) no

19. I have taken part in a demonstration in the interest of safeguarding the global or local environment

☐ a) yes

☐ b) no

20. I am a member of one or more public interest environmental groups

☐ a) yes

☐ b) no

Your Score: Score yourself this way: every a = 3 points; b = 0 points; c = 2 points; d = 1 point.

0 - 24 There are lots of things you can start doing to save the environment..

25 - 45 You've taken the important first steps. Expand your conservation activities and you might save the environment.

Over 45 Keep up the valiant effort. Be a living example that you can save the environment.